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CONSTRUCTION CONTRACT RISK ASSIGNMENT.(U)
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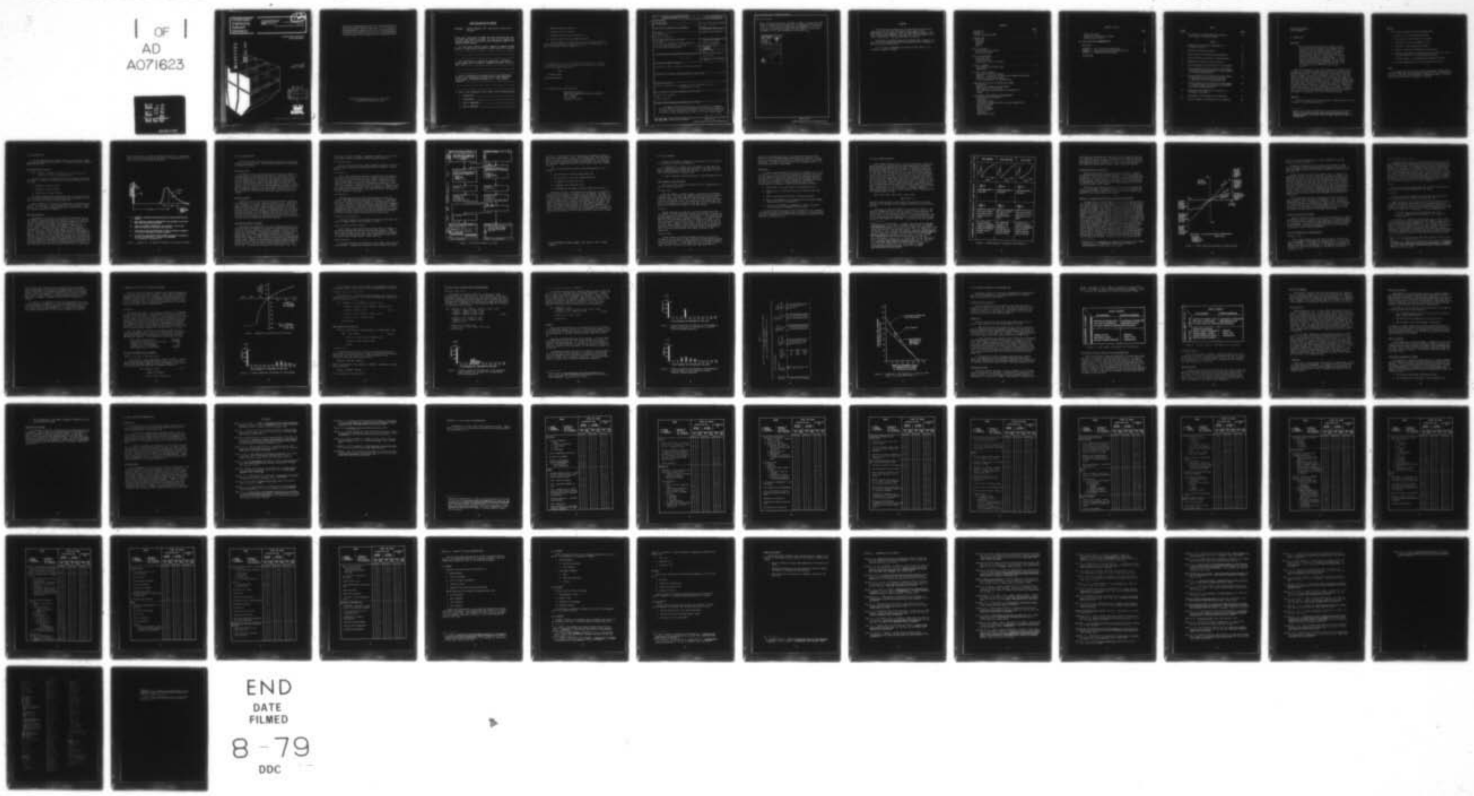

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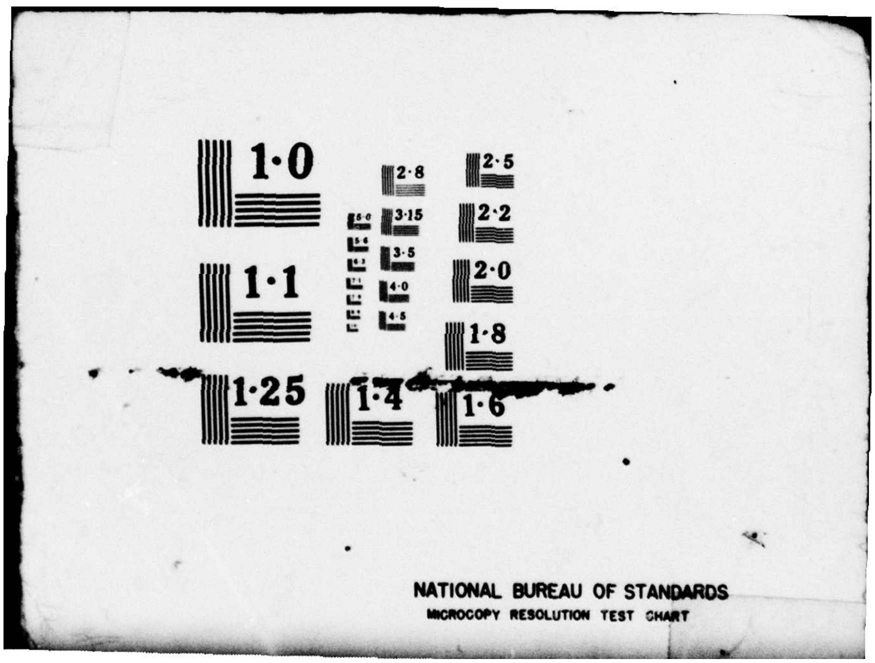
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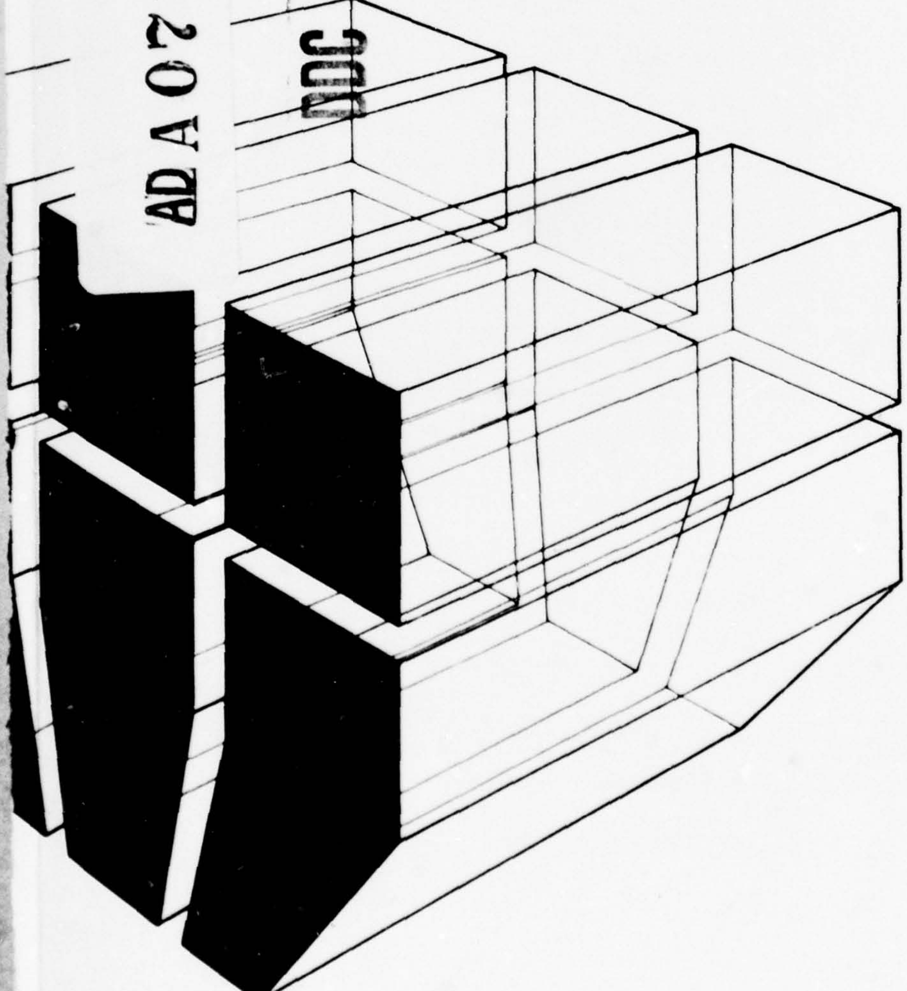
TECHNICAL REPORT P-101
June 1979
Risk Assignment in Military Construction

CONSTRUCTION CONTRACT RISK ASSIGNMENT



by
Carl A. Erikson
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This report presents the results of an investigation to determine the cost effects of varying the assignment of risk between the owner and contractor in firm fixed-price construction contracts. Among the topics included are a working definition of risk, a risk classification upon cont

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which a construction process risk model is based, a discussion of techniques for contractually assigning risk, a discussion of the applicability of utility theory for analyzing the assignment of risk in construction, an example which models the cost effects of varying the assignment of risk, and implementation considerations.

FOREWORD

This research was conducted for the Directorate of Military Programs, Office of the Chief of Engineers (OCE), under Project 4A161102AT23, "Basic Research in Military Construction"; Task A2, "Military Construction Management"; Work Unit 005, "Risk Assignment in Military Construction." The applicable QCR is 1.01.018.

The work was performed by the Facility Systems (FS) Division, U.S. Army Construction Engineering Research Laboratory (CERL), Champaign, IL. Mr. E. A. Lotz is Chief of FS.

COL J. E. Hays is Commander and Director of CERL and Dr. L. R. Shaffer is Technical Director.

CONTENTS

CONTENTS (cont'd)

TABLES

FIGURES

CONSTRUCTION CONTRACT
RISK ASSIGNMENT

1 INTRODUCTION

Background

> "What threatens the stability and financial security of the construction industry is not design, but the problem of distributing the risks inherent in the construction process among the owner, the construction contractor, and the architect and engineer.... Underlying this subject is the viability of the construction industry as it is known today.... The industry cannot be healthy unless the risks are forthrightly recognized and acknowledged, and the various contracting parties assume under the contract, without ambiguity, their respective parts of the risk."[1]

Many of the problems in the area of construction process risk assignment arise because the owner traditionally uses exculpatory and hold-harmless clauses to avoid obligations in construction contracts. Doing so, however, may not be in the owner's best interest since the owner can select the type and provisions of the contract. When contractors are obliged to assume the risk, they include contingency costs for events that often do not actually occur. Litigation resulting from such construction contracts is not only costly and time consuming, but frequently results in decisions favoring the contractor. Owners who are willing to share risk with a contractor in an attempt to obtain smaller contingencies, and thus reduce the expected cost of a construction project, find that no systematic approach has been developed to guide them in the selection of a risk-allocation strategy.

Objective

The overall objective of this study was to develop models for risk allocation in construction contracts.

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[1] Douglas, W. S.,"Role of Specifications in Foundation Construction," Journal of the Construction Division, American Society of Civil Engineers (ASCE), Vol 100, No. CO2, Proc Paper 10570 (June 1974), pp 199 and 201.

Approach

This study was conducted in the following steps:

1. Define risk in the construction process

2. Identify risks in the construction process

3. Delineate the current assignment of risk

4. Formulate a risk-categorization scheme

5. Formulate contractual techniques for sharing risk

6. Develop an approach for evaluating the cost effects of varying the allocation of risk in construction contracts

7. Provide guidance for implementing the approach developed

8. Provide recommendations for further work on this topic.

Scope

This study was limited to the areas of procurement strategy, selection of contract type and provisions, and administration of construction contracts. The results are applicable to the general types of construction in which the Corps of Engineers is involved.

2 RISK DEFINITION

Literature addressing the problems of risk in construction seldom clarifies the meaning of the term *risk*. This chapter presents a working definition of risk.

Working Definition of Risk

Risk: Exposure to possible economic loss or gain arising from involvement in the construction process.

The risks to which a construction activity is exposed can be identified and it is possible to describe the following characteristics of the risks:

1. Frequency of losses or gains
2. Severity of losses or gains
3. Variability of losses or gains.

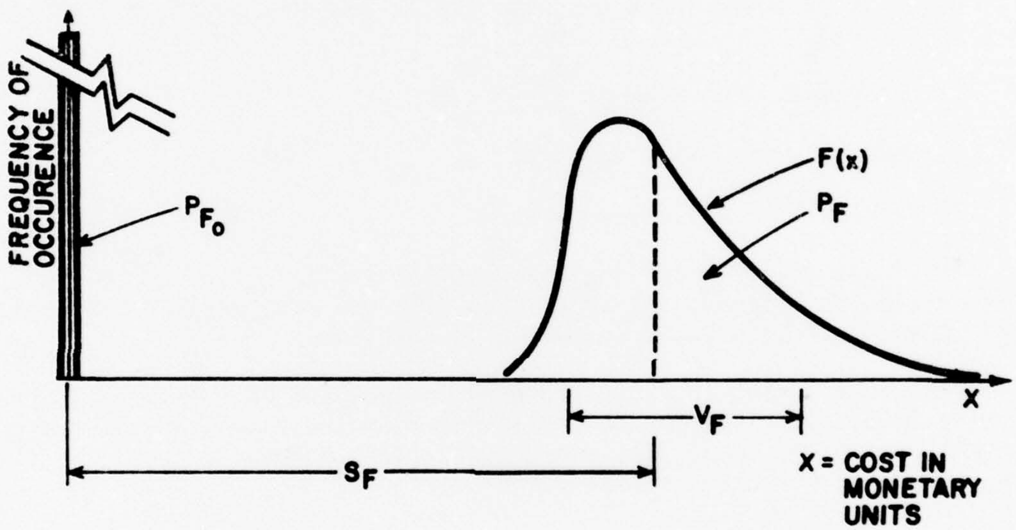
The frame of reference for the possible loss or gain may be relative to the anticipated cost associated with the risk exposure, or relative to an ideal cost based on optimal conditions.

Risk is inherent in a construction project and is allocated to the parties involved; risks can be considered from the viewpoints of these parties, i.e., the owner, designer, contractor, subcontractors, suppliers, insurers, sureties or financiers.

Descriptive Aspects

Consideration of alternative risk-allocation strategies requires the identification and evaluation of individual risks in the construction process, emphasizing those risks which are deemed most important. Figure 1 illustrates the concepts of frequency, severity, and variability which are indicators of the amount of attention a risk warrants. Figure 1 assumes a 30 percent probability of occurrence (P_F=0.30) of a flood affecting costs, and a 70 percent probability of nonoccurrence (P_{FO} = 0.70) of a flood affecting costs. Note that P_F + P_{FO} = 1. Given that a flood affecting costs occurs, the estimated average cost is of some severity or magnitude, S_F, and the variability, V_F, indicates the variation of costs about the average cost. An evaluation of the risk must not only consider the uncertainty indicated by V_F, but also must consider the uncertainty of whether or not all pertinent risks have been identified. The evaluation should concentrate on risks with high frequencies, high severities, high variabilities, or combinations

thereof which yield a substantial expected value of loss. The management of these risks must consider the degree of control possible for reducing the risk or mitigating its effects.



F(x) = FREQUENCY DISTRIBUTION FUNCTION GIVEN THAT A FLOOD AFFECTING COSTS OCCURS

P_F = AREA UNDER THE CURVE F(x), REPRESENTING THE PROBABILITY OF OCCURRENCE FOR A FLOOD AFFECTING COSTS.

P_{F_0} = AREA AT THE ORIGIN, REPRESENTING THE PROBABILITY THAT A FLOOD AFFECTING COSTS WILL NOT OCCUR. NOTE: $P_F + P_{F_0} = 1$

S_F = GIVEN THAT A FLOOD AFFECTING COSTS OCCURS, S_F INDICATES THE SEVERITY OR SIZE OF THE COSTS THAT MAY BE INCURRED.

V_F = GIVEN THAT A FLOOD AFFECTING COSTS OCCURS, V_F INDICATES THE VARIABILITY OF COSTS THAT MAY RESULT. IT REFLECTS THE DISPERSION OF OUTCOMES ABOUT THE MEAN OF F(x).

Figure 1. Hypothetical risk exposure assessment for possible flooding.

3 RISK CLASSIFICATION

Risks in the construction process can be classified as contractual risks or construction risks. The differences between these two classes are defined as follows.

Contractual Risk

Contractual risks arise primarily from the interaction among the different parties to the construction process. Contractual risk is introduced through lack of contract clarity, absence of perfect communication between the parties involved, and problems of timeliness in contract administration. These risks expose both the owner and contractor to uncertainties which may increase both parties' costs. Contractual risks are not risks to be shared; however, the owner can reduce them by improving contract clarity and contract administration. The cost of reducing contractual risk may be small relative to the cost of the uncertainties, inefficiencies, and delays which contractual risk creates.

Construction Risk

Construction risk arises from factors such as weather, differing site conditions, acts of God, resource availability, etc. Construction risk is inherent in the work itself and would be present even if one company with perfect internal communication performed all of the construction process functions itself. Although construction risks may be reduced, they are primarily managed by assigning them to one or more of the parties involved. This assignment should consider factors such as comparing the differing utility functions of each of the parties, maintaining contractor incentives, and determining which party can best control the risk or influence the severity of the loss.

Construction Process Risk Model

Contractual and construction risk can be incorporated into a construction process risk model to facilitate risk-sharing formulation and evaluation. As the construction process risk model in Figure 2 illustrates, both contractual- and construction-oriented risks may result in project and cost changes, and different techniques are required to manage these risks. The model shows that risks can be jointly examined from both the viewpoints of the parties involved and by considering the project itself. Parties to the construction process emphasize monetary considerations, whereas the primary project considerations are physical aspects and time. (See the left and right margins of Figure 2, respectively.) A step-by-step discussion of the bracketed items in the

left margin of Figure 2 follows. (Appendix A presents a list of risks which owners should review when evaluating current contracts.)

Starting Conditions

Parties to the construction process assemble to construct the envisioned project; interactions among the parties are viewed as a closed system.

Risk Exposure

Risks in the construction process are theoretically classified as contractual risks or construction risks. However, many risks may be viewed as some combination of these two classes. Contractual risk is risk introduced due to a lack of contract clarity, absence of perfect communication between the parties, and problems of timeliness in contract administration. Construction risk is risk that is inherent in the work itself and would be present even if one company with perfect internal communication performed all of the functions itself. This phase is the most important in the model.

Risk Management

Although contractor bids include contingencies for both contractual- and construction-oriented risks, the owner's risk management policies can greatly influence the amount of contingency paid to the contractor. An owner can reduce contractual risks by better management, i.e., improved contract clarity and contract administration. However, it should be noted that construction risks are managed primarily by assigning them to one or more of the parties to the construction process. Assignment of these construction risks should consider the differing utilities for money at which the various parties assess risk.

Occurrence or Nonoccurrence

This phase represents the occurrence of uncertain events which may result in project impacts, dollar impacts, or both.

Project Impacts and Dollar Impacts

Both contractual and construction risks may result in changes to the original project plans and its original cost estimates. These impacts may be viewed as iterative; i.e., the occurrence of the uncertain events may cause project impacts which cause dollar impacts which in turn may cause further project impacts, and so on.

Ending Conditions

This phase represents the completion of the project, when the envisioned project, as changed by the project impacts, becomes the project

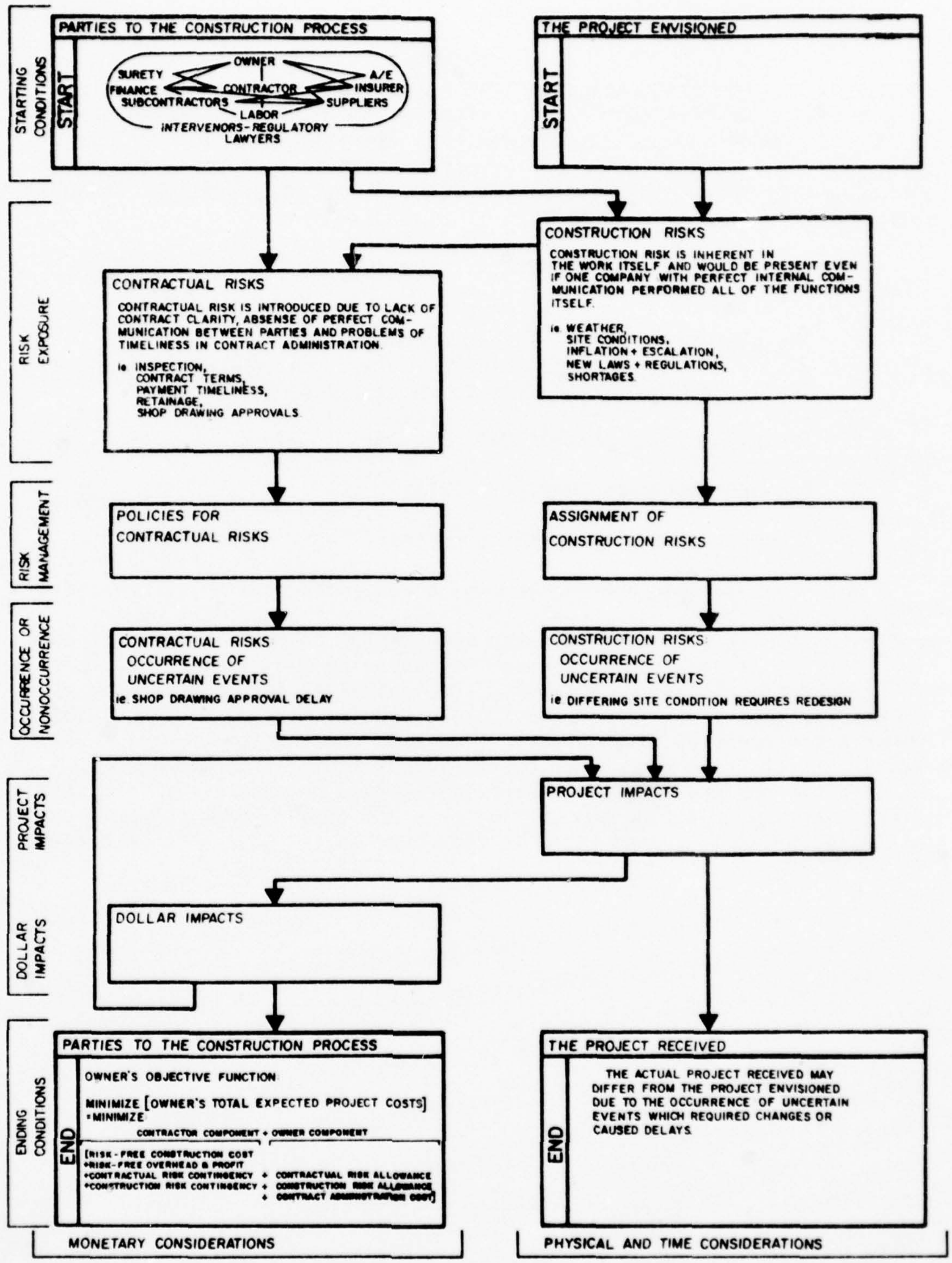


Figure 2. Construction process risk model.

received. On the financial side, the owner has attempted to maximize the project's benefit/cost ratio. After determining a specified quality level, the owner's objective becomes cost minimization. The project's cost of risk is one such cost to be minimized and is one that the owner can influence through his* selection of the contract provisions assigning risk.

Under a firm fixed-price contract, the expected project cost includes:

1. The contractor's risk-free construction cost

2. The contractor's risk-free overhead and profit

3. A component for contractual risk

4. A component for construction risk

5. A component for the owner's contract administration costs.

Note that in Figure 2 the component for contractual risk may be included as the contractor's contractual risk contingency, the owner's contractual risk allowance, or some combination thereof. The total cost for contractual risk can be reduced by improving the terms and administration of the contract. Similarly, the component for construction risk may be included as the contractor's construction risk contingency, the owner's construction risk allowance, or some combination thereof. The total cost of these components may vary substantially depending upon whether the owner or the contractor is assigned responsibility for this risk. The sum of all of the contractor's and owner's risk components is minimized by assigning the risk to the party who is best able to assume it.

* The male pronoun is used throughout this report to refer to both genders.

4 TYPES OF SHARING

The owner interested in assuming a larger share of the risk under a firm fixed-price contract must determine:

1. How much risk to assume; e.g., in general, a large owner may find it advantageous to decrease the contractor's risk share to a point where a further decrease reduces the contractor's incentives for efficient performance below an adequate level.

2. How to implement risk-sharing policy. (See following section.)

Three Methods of Assigning Risk

There are several contractual possibilities for implementing risk-sharing. Three of these are:

Percentage Basis

Under this method, the owner assumes a percentage of the damages resulting from a particular risk exposure, while the contractor retains a smaller share. The percentage basis method should reduce the contractor's contingency, since there is less likelihood of the contractor incurring a catastrophic loss. The advantage of this method over complete risk assumption by the owner is that the contractor's share helps maintain the contractor's incentive to mitigate losses.

Deductible

Another approach is to specify a contractor-assumed deductible. For example, a $20,000 deductible requires the contractor to assume the risk for losses less than $20,000. The portion of a loss exceeding the $20,000 deductible would be assumed by the owner. A contractor-assumed deductible frees the owner from small claims which are costly to process, and provides the contractor with an incentive to manage the construction risks. However, the contractor is not given an incentive to try to mitigate the owner's losses after the losses have surpassed the deductible. This method should also reduce contractor contingencies, since it protects the contractor from losses in excess of the deductible.

Combined Method

Another method of maintaining adequate contractor incentive to mitigate loss is to specify a small contractor-assumed deductible above which risks are shared on a percentage basis, e.g., 80 percent owner to 20 percent contractor. A small deductible, such as $10,000, frees the owner from small nuisance claims which have high administrative

verification and processing costs. The 20 percent contractor share beyond the initial $10,000 deductible maintains the contractor's incentive to mitigate owner losses after the contractor's losses surpass the deductible. It should be noted that this risk assignment results in an inconsequentially small risk premium.

Application

The methods described above do not have to be adopted for all risks in a contract. Initially, owners are advised to cautiously adopt risk-sharing clauses to cover only a few specific risk exposures for which the owner feels the contractor may be including the largest amounts of contingency. This selection should consider the implementation considerations noted in Chapter 7. The determination of the actual percentages and the deductible amount to be used should consider:

1. Which party, if any, can control or influence the risk?
2. Which party is in the best position to financially bear the risk?
3. What is the administrative cost of processing claims?
4. What is the probability of occurrence and the possible damages associated with the risk exposure?
5. Is this risk dependent or independent of other risks which could have severe consequences on the project?

The new risk-sharing clauses could be incorporated into the owner's conventional contract by including them as alternates. This would allow the owner to determine the effects of the risk-sharing clauses by direct comparison with the base bid.

5 UTILITY THEORY CONCEPTS*

Utility theory proposes that an individual faced with a choice between alternatives with uncertain outcomes chooses that alternative which maximizes the expected value of what is referred to as utility. The theory contends that if the individual is indifferent between two alternatives, then the expected utility of the alternatives is equal. An individual's utility function can be established by asking the individual a series of questions. This process involves arbitrarily defining utility values for any two dollar amounts, subject only to the restriction that the larger dollar amount be assigned the larger of the two utility values. After defining these two points, the utility values for all other profits may be uniquely determined. For example, let A and C represent two possible dollar profits with probabilities of occurrence of P(A) and P(C). Let U(A) and U(C) represent the utilities of A and C, respectively. If the individual is indifferent between a cash-certain equivalent B or a lottery between A and C, the utility of B can be determined as follows:

$$EUV = U(A) \times P(A) + U(C) \times P(C) = U(B) \times P(B)$$

$$\text{where } P(B) = 1.$$

Solving for U(B) provides a third point on the individual's utility function. This procedure can be repeated to determine as many points as desired.[2]

Three plots of such relationships are contained in Figure 3. The abscissa represents profits in dollars and the ordinate represents the profit's utility value equivalents expressed in an arbitrary scale called utiles. All of the three types of risk-preference behaviors have utility functions which are monotonically increasing, indicating a preference for more money over less money. The second derivatives indicate

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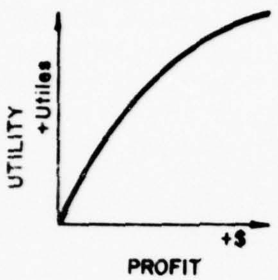
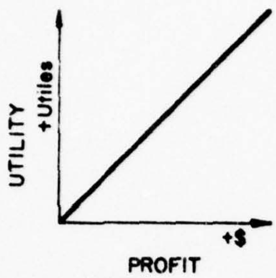
[2] Swalm, R. O., "Utility Theory -- Insights into Risk Taking," Harvard Business Review, Vol 44, No. 6 (November-December 1966), pp 123-136.

*The fundamental concepts of cardinal utility theory are summarized in this chapter and applied in the following chapter. For more information, see von Neumann, J. and O. Morgenstern, Theory of Games and Economic Behavior, Edition 3 (John Wiley and Sons, 1953), and Luce, R. D. and H. Raiffa, Games and Decisions (John Wiley and Sons, 1957), pp 12-28, 371-384; for a discussion of the construction-oriented applications and the utility theory, see Carr, R. I., "Paying the Price for Construction Risk," Journal of the Construction Division, ASCE, Vol 103, No. CO1, Proc Paper 12827 (March 1977), pp 153-161 and Willenbrock, J. M., "Utility Function Determination for Bidding Models, Journal of the Construction Division, ASCE, Vol 99, No. CO1, Proc Paper 9843 (July 1973), pp 133-153.

TYPE	RISK AVERSE	RISK NEUTRAL	RISK TAKER
UTILITY FUNCTION			
FIRST DERIVATIVE	$\frac{dU}{dP}>0$ PREFER MORE MONEY TO LESS MONEY	$\frac{dU}{dP}>0$ PREFER MORE MONEY TO LESS MONEY	$\frac{dU}{dP}>0$ PREFER MORE MONEY TO LESS MONEY
SECOND DERIVATIVE	$\frac{d^2U}{dP^2}<0$ SUBJECTIVELY VALUE THE NEXT DOLLAR OF PROFIT LESS HIGHLY THAN THE PREVIOUS DOLLAR OF PROFIT	$\frac{d^2U}{dP^2}=0$ SUBJECTIVELY VALUE THE NEXT DOLLAR OF PROFIT THE SAME AS THE PREVIOUS DOLLAR OF PROFIT	$\frac{d^2U}{dP^2}>0$ SUBJECTIVELY VALUE THE NEXT DOLLAR OF PROFIT MORE HIGHLY THAN THE PREVIOUS DOLLAR OF PROFIT
INTERPRETATION	WILL NOT WILLINGLY ASSUME RISK EXPOSURE UNLESS THE COMPENSATION EXCEEDS THE EXPECTED MONETARY VALUE OF THE RISK	WILL ASSUME RISK EXPOSURE IF THE COMPENSATION IS NOT LESS THAN THE EXPECTED MONETARY VALUE OF THE RISK	MAY BE WILLING TO ASSUME RISK EXPOSURE EVEN IF THE COMPENSATION IS LESS THAN THE EXPECTED MONETARY VALUE OF THE RISK





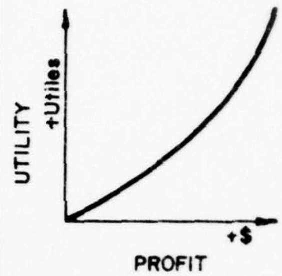


Figure 3. Classification of individual risk preferences.

a difference in the subjective values placed on the marginal utilities of an additional dollar of gain. Although Figure 3 shows the three distinct possibilities of risk behavior, the plot of an individual's risk preferences may contain portions of all three curves since an individual's behavior may vary over different ranges of possible profits.

Comparison of Utility Functions

Utility values cannot be compared between individuals. However, the predictions made from different individuals' utility functions can be compared. The utility functions themselves are not comparable since neither the zero nor the unit of a utility scale imply any inherent absolute meaning. Utility values are meaningful only for the individual for whom they were derived and only then when compared relative to the individual's other utility values.

Although a quantitative comparison of utility values between individuals is impossible, the general shapes of the utility functions can be compared to indicate whether the individuals are risk averse, risk neutral, or risk takers over similar ranges.

Behavior: Is Expected Utility Value an Appropriate Measure?

The application of utility theory to risks in the construction process provides a means to predict behavior. The use of expected utility value (EUV), appears to be justified on both its own merits and because its predictions appear to be better than predictions based on expected monetary value (EMV). For instance, suppose an individual had the good fortune to be given a lottery ticket for a lottery having a 50 percent probability of winning $200,000 and a 50 percent probability of winning nothing. If the individual behaves like most persons in this situation might, he may be willing to sell the ticket for some certain amount less than the EMV of $100,000. The EUV of the certain sum at which the individual would be indifferent between selling the ticket or keeping it has the same EUV as the 50-50 chance at $200,000 or $0. Figure 4 illustrates how a hypothetical contractor might behave when given the opportunity to participate in such a lottery, i.e., a 50-50 chance of an outcome which is either $0 or a prize of specific monetary gain or loss.[3] The EMV line is a plot whose abscissa is the lottery prize and the ordinate is the EMV of the lottery which is the cash-certain equivalent at which a risk-neutral individual would appraise the lottery. The hypothetical contractor line deviates substantially from the EMV line as the prize increases. On the left end of the curve, the plot

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[3] Erikson, Carl A., Risk Sharing in Construction Contracts, Ph.D. Thesis (Department of Civil Engineering, University of Illinois at Urbana-Champaign, January 1979), pp 19 and 20.

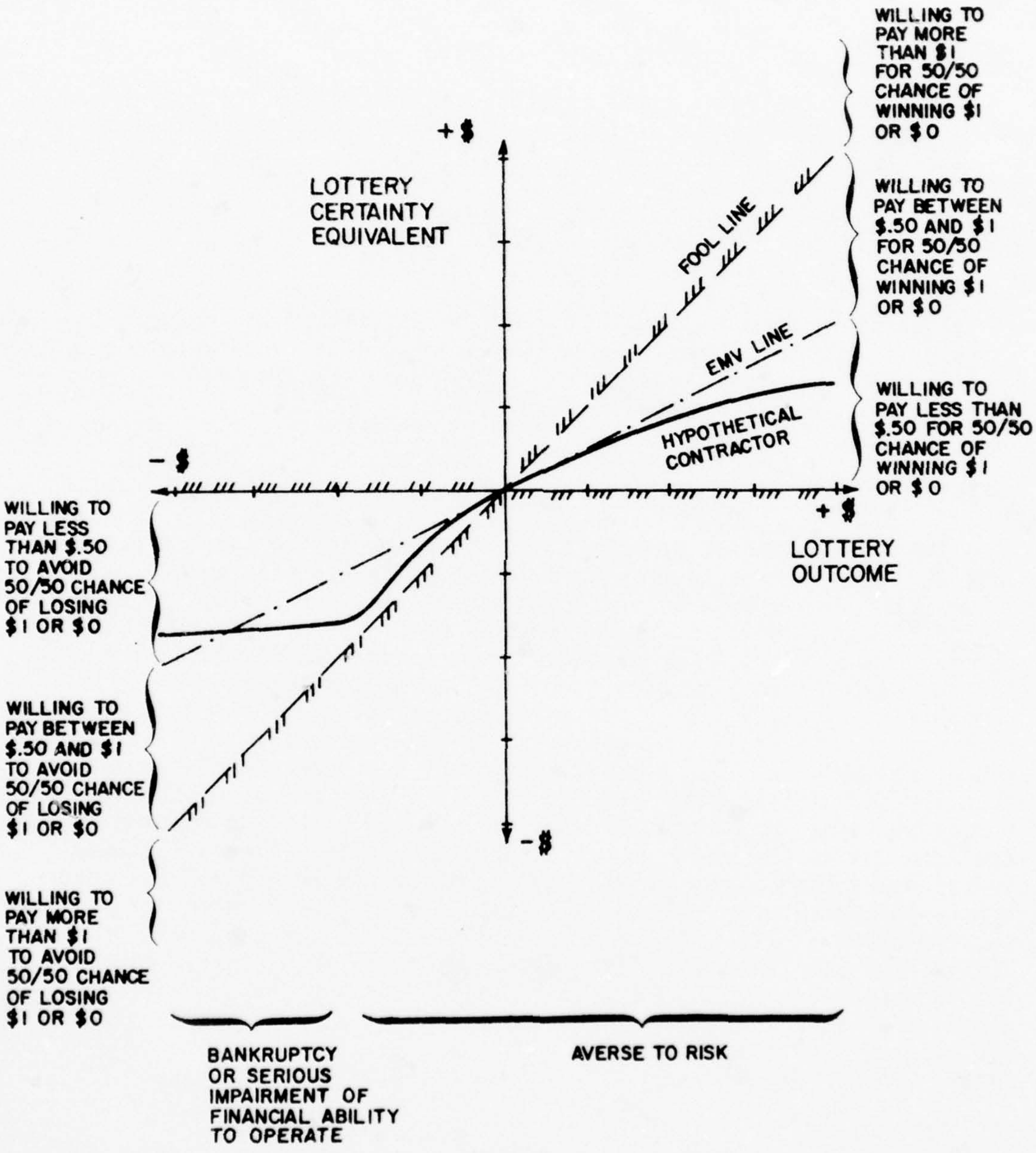

Figure 4. Lottery certainty equivalent vs lottery outcome.

levels off, signifying bankruptcy or serious impairment of the contractor's ability to operate.

Throughout the remainder of this report, the assumption is made that in any choice between alternatives with outcomes involving risk, an individual selects that alternative which maximizes the individual's expected utility.

Another justification for not using EMV is that it implies a frequency point of view. At small stakes, an individual may behave in an EMV manner and agree to flip a coin one thousand times in a game where heads wins $1 and tails loses $1. The same individual may be quite unwilling to agree to flip only once for a single win or loss of $1,000, even though the EMV of both of the games is $0. Such may well be the case for a construction contractor who may decide that going bankrupt in the short run would not allow the opportunity to amass average profits in the long run. In addition, a large owner might be better able to sustain a large loss on a particular project because the losses should average out in the long run over several projects and approach an expected value.

Utility theory can be used to evaluate the price differential between an owner's and a contractor's assessment of risk. In general, large owners may find it advantageous to assume a larger share of the risk in firm fixed-price contracts since contractors' risk contingencies are greater than the value at which large owners assess risk. In specific cases, utility theory also shows potential as a way to evaluate how much of the construction risk the owner should assume.

Prediction Using Utility Theory

Once an individual's utility function has been determined, it should be possible to use it to predict the individual's risk preference behavior in risk situations similar to those under which the utility function was formulated. If factors such as the individual's financial position or the economic situation have changed since the utility function was formulated, a new one should be generated.

Critical Assumptions for Implementation

Maximize Utility

Utility theory assumes that individuals attempt to maximize utility. The assumption that contractors and owners behave in this manner appears reasonable. For example, if a large owner is risk neutral, he behaves on an EMV basis (see Chapter 6). The approach also remains applicable for cases in which the owner is not EMV, but continues to maximize utility.

Utility Function Known to Owner

The owner should be able to derive a utility function for his firm. Owner knowledge of the contractor's utility function is not usually essential. For instance, in the general case in which the objective is to demonstrate that it may be in the owner's best interest to assume more of the risk, a hypothetical contractor utility function which is more risk averse than the owner's may be used. If the application is a specific case of determining how much risk to share, a contractor's utility function can be effectively determined by specifying bids on a number of alternates in which all factors remain constant except the risk shares. The difference in the bids reflects the contractor's appraisal of risk and can be directly compared to the owner's appraisal.

Damages

The utility function model assumes that the owner and contractor both perceive the possible damages to be the same.

Probability

The utility function model also assumes that the owner and contractor both perceive the probabilities to be the same.

Rowe[4] states that even in the face of historical probability data, individuals may behave differently than may be expected because of *probability thresholds*. Some critics of the potential benefits of risk sharing claim that contractors do not include contingencies because they would not be competitive. Conversely, it is also contended that:

> "A rational participant will only accept risk if he receives a commensurate reimbursement for the acceptance of that risk."[5]

The concept of a probability threshold may explain these issues. Risks which have very small probabilities may simply be ignored by contractors when determining contingencies. This threshold may be at a level of risks with probabilities of less than 1 percent and possibly as high as risks with probabilities of less than 5 percent. The consequence of ignoring very low probability risks which have potentially catastrophic consequences is that the contractor is exposed to financial ruin and the owner is exposed to delays and claims by the contractor.

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[4] Rowe, W. D., An Anatomy of Risk (John Wiley and Sons, 1977), pp 319-20.

[5] Richards, J. L., "Construction Contractual Relationships," Proceedings of the CIB W-65 Symposium on Organization and Management of Construction (U.S. Army Construction Engineering Research Laboratory [CERL], May 19-20, 1976), p II-200.

The contention that contractors will not accept risk without commensurate reimbursement is also suspect because when work is scarce, contractors with high fixed overhead and equipment costs can be literally forced to take risky projects at an expected loss in order to minimize their overall losses and hope to survive to enjoy better times. And once again, the owner is exposed to the possibility of delays and claims.

In addition to a threshold for risks with low probabilities, contractors may base contingencies on risks with probabilities which exceed an upper threshold, such as 80 percent, as if their probability was 1.00. Risks with mid-range probabilities -- 5 percent to 80 percent -- are probably appraised based on their actual probability estimates.

6 MODELING COST EFFECTS OF VARYING RISK SHARES

The cost effects of varying risk shares can be modeled by applying the principles of cardinal utility theory. Such a model's fundamental assumption is that a contractor attempts to maximize utility and is indifferent between different risk assignments for which the contractor's utility remains the same. The model presents the cost effects of complete risk assignment and risk sharing by percentage basis, contractor-assumed deductibles, and on a combined basis.

Assumptions

The hypothetical owner is risk neutral and behaves in an expected monetary value, EMV, manner. The contractor is risk averse within the relevant range considered (see Figure 5). The contractor's bid includes (1) the project's anticipated risk-free costs of $1,000,000, (2) a 10 percent mark-up of anticipated risk-free costs, and (3) an additional contingency for flood risks assigned to the contractor by the owner. The contractor's flood risk contingency is determined by varying the contractor's total mark-up (2+3) such that the contractor's EUV for the project remains constant regardless of the contractor's risk share.

The risk exposure considered is a 30 percent probability that a flood causing damage occurs. Given that a flood occurs, the damage is specified by the discrete probability distribution with a mean of $200,000 (see Figure 6). The assumptions are summarized as follows:

Anticipated risk-free costs:	$1,000,000
Mark-up at 10 percent of risk-free costs:	$100,000
Probability of flood damage:	0.30
Probability of no flood damage:	0.70
Mean damage given a flood occurs:	$200,000

Appraisal of Complete Risk Assignment

Contractor Appraisal of Risk-Free Project

The contractor's utility function, as shown in Figure 5, indicates the risk-free mark-up of $100,000 yields a utility of 47.9 for the project when the owner assumes the flood risk (monetary values in the following equations are expressed in thousands of dollars):

$$EUV = \Sigma (U[X_i] \times P[X_i]) \qquad \text{[Eq 1]}$$

$$= U(\$100.0) \times P(100.0)$$

$$= 47.90 \times 1.00 = 47.90 \text{ utiles}$$

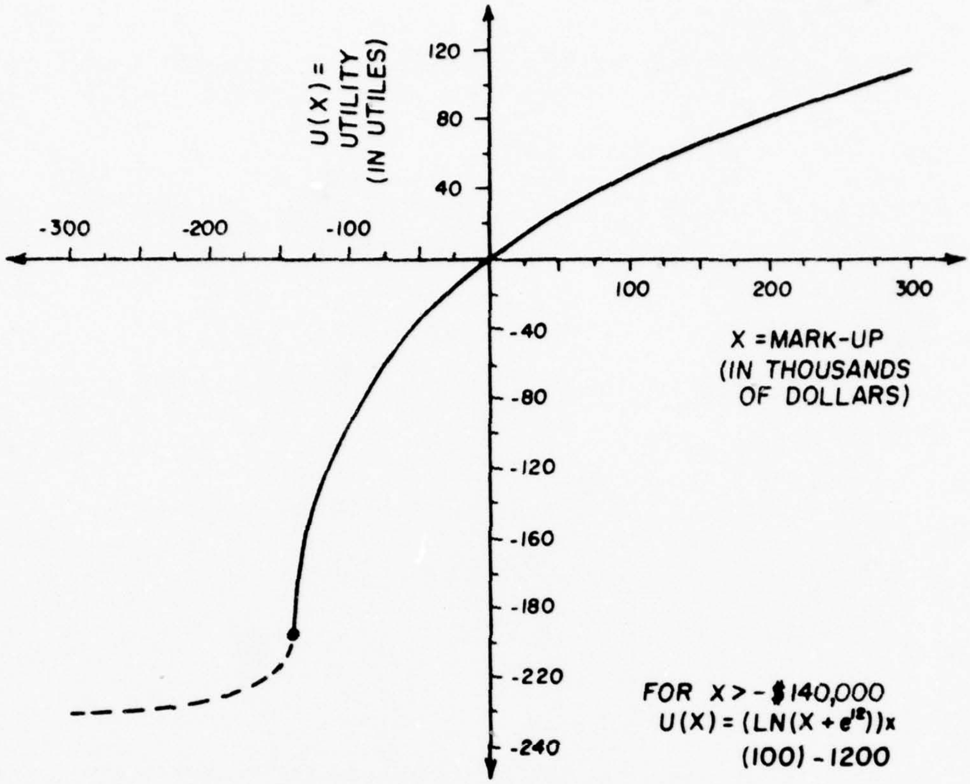

Figure 5. Hypothetical contractor utility function.

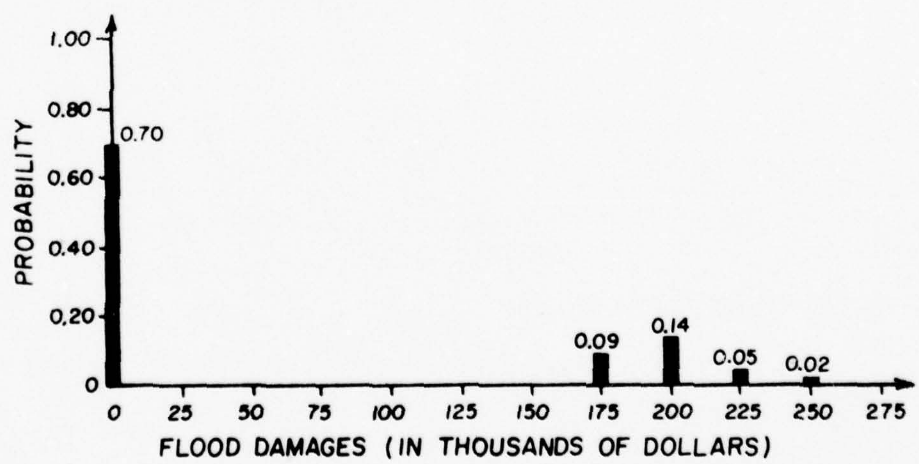

Figure 6. Discrete probability distribution of flood damages.

The contractor's mark-up for all other risk assignments will be determined by finding a mark-up which yields the same EUV of 47.9 utiles.

Contractor Appraisal of Flood Risk

The contractor's risk appraisal when assigned all the flood risk is described in Eq 2. Note that a total mark-up of \$180,166 is required to yield an EUV of 47.9 utiles.

$$\begin{aligned} EUV &= U(\$180.2) \times 0.70 + U(\$180.2 - \$175.0) \times 0.09 \\ &\quad + U(\$180.2 - \$200.0) \times 0.14 + U(\$180.2 - \$225.0) \times 0.05 \\ &\quad + U(\$180.2 - \$250.0) \times 0.02 \qquad \text{[Eq 2]} \\ &= 74.53 \times 0.70 + 3.12 \times 0.09 + (-13.00 \times 0.14) \\ &\quad + (-32.22 \times 0.05) + (-56.05 \times 0.02) \\ &= 47.90 \text{ utiles} \end{aligned}$$

Owner Appraisal of Flood Risk

Since it is assumed that the owner behaves in an EMV manner, then

$$\begin{aligned} EMV &= \Sigma(X_i \times P[X_i]) \qquad \text{[Eq 3]} \\ &= \$0 \times 0.70 + \$175.0 \times 0.09 + \$200.0 \times 0.14 \\ &\quad + \$225.0 \times 0.05 + \$250.0 \times 0.02 \\ &= \$60.0 \end{aligned}$$

Interpretation

Utility theory predicts the contractor should be indifferent between taking a risk-free project at a mark-up of \$100,000 and taking the same project including flood risk at a \$180,166 mark-up. The risk-averse contractor appraises the risk at

\$180,166 - \$100,000 = \$80,166

whereas the EMV owner's risk appraisal is \$60,000. Therefore, the owner pays a premium of

\$80,166 - \$60,000 = \$20,166

for the contractor to assume the risk.

Risk Sharing by Percentage Basis and Deductibles

Percentage Basis 50-50

The contractor's appraisal when risk is shared on a 50-50 percentage basis is described in Eq 4. Note the effect of sharing illustrated in Figure 7 when compared to the original probability distribution of flood damages shown in Figure 6, i.e., the percentages remain unchanged but the damages are halved because the owner and contractor are sharing on a 50-50 basis. A total mark-up of $134,529 is required to yield an EUV of 47.9 utiles.

$$\begin{aligned}
EUV &= U(\$134.5) \times 0.70 + U(\$134.5 - (\$175.0 \times 0.50)) \times 0.09 \\
&\quad + U(\$134.5 - (\$200.0 \times 0.50)) \times 0.14 \\
&\quad + U(\$134.5 - (\$225.0 \times 0.50)) \times 0.05 \\
&\quad + U(\$134.5 - (\$250.0 \times 0.50)) \times 0.02 \qquad \text{[Eq 4]} \\
&= U(\$134.5) \times 0.70 + U(\$47.0) \times 0.09 \\
&\quad + U(\$34.5) \times 0.14 + U(\$22.0) \times 0.05 \\
&\quad + U(\$9.5) \times 0.02 \\
&= 60.24 \times 0.70 + 25.38 \times 0.09 \\
&\quad + 19.24 \times 0.14 + 12.69 \times 0.05 + 5.69 \times 0.02 \\
&= 47.89 \text{ utiles}
\end{aligned}$$

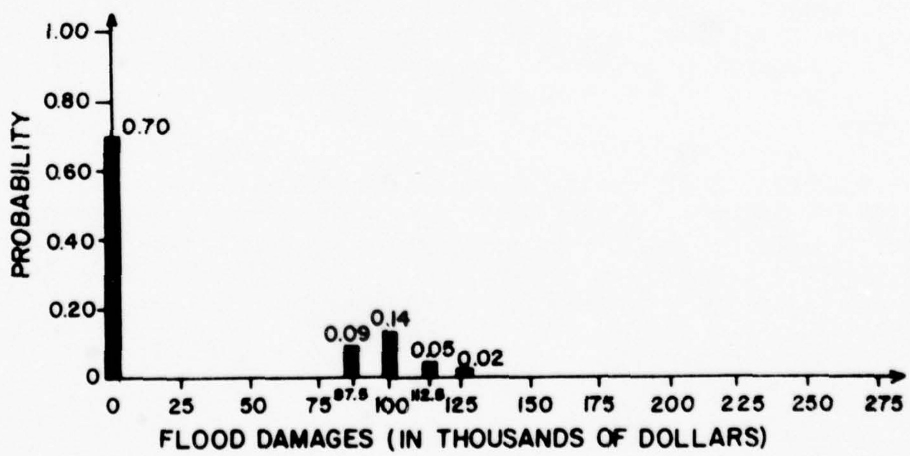

Figure 7. Discrete probability distribution of flood damages as viewed by owner and contractor for risk sharing on 50-50 percentage basis.

Contractor-Assumed Deductible: $100,000

Eq 5 presents the contractor's appraisal when the owner assumes the risk in excess of a $100,000 contractor-assumed deductible. Figures 8 and 9, respectively, show the contractor's and owner's views of their own risk shares under this assignment. Note that the contractor views his own risk merely as the deductible, whereas the owner views his risk shown as the original distribution translated to the left by the $100,000 deductible assumed by the contractor. A total mark-up of $134,412 is required to yield an EUV of 47.9 for the contractor.

$$\begin{aligned} EUV &= U(\$134.4) \times 0.70 + \\ &\quad + U(\$134.4 - \$100.0) \times (0.09 + 0.14 + 0.05 + 0.02) \\ &= U(\$134.4) \times 0.70 + U(\$34.4) \times 0.30 \qquad \text{[Eq 5]} \\ &= 60.20 \times 0.70 + 19.18 \times 0.30 \\ &= 47.89 \text{ utiles} \end{aligned}$$

Summary

Because the model based on utility theory predicts the contractor to be indifferent between alternatives in the preceding examples, it can be concluded that an EMV owner pays more to the risk-averse contractor for the contractor to assume risk than the owner should be willing to pay.

Note that the methodology used in this chapter is also applicable to non-EMV owners who are less risk averse than the contractors with whom they are being compared. For instance, in the first example, a non-EMV, risk-averse owner who is less risk averse than the contractor would pay a premium of less than $20,170 if the contractor assumes all of the risk.

The preceding examples and additional examples of the cost effects of varying the owner's and contractor's risk shares on a percentage basis and through the use of contractor-assumed deductibles are summarized in Table 1 and illustrated in Figure 10. The data upon which Table 1 and Figure 10 are based were generated by computer.[6]

[6] Erikson, Carl A., Risk Sharing in Construction Contracts, Ph.D. Thesis (Department of Civil Engineering, University of Illinois at Urbana-Champaign, January 1979), pp 114-121.

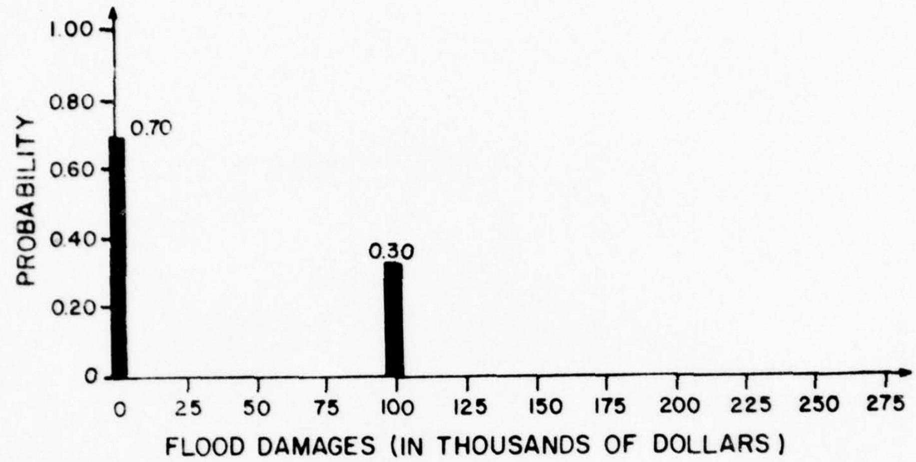

Figure 8. Discrete probability distribution of flood damages as viewed by contractor for risk sharing by $100,000 contractor-assumed deductible.

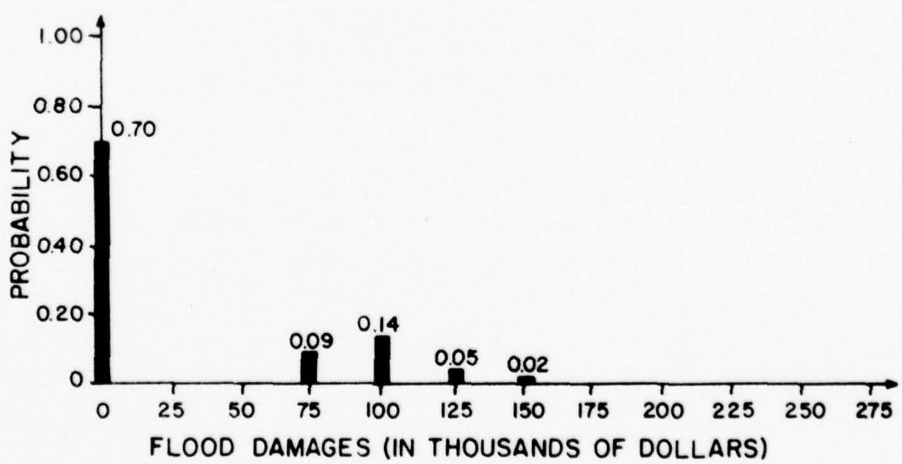

Figure 9. Discrete probability distribution of flood damages as viewed by owner for risk sharing by $100,000 contractor-assumed deductible.

Table 1

Cost Effects of Varying Owner and Contractor Risk Shares
for Example Problem
(not including contract administration costs)

--Risk Assignment--						
Owner % of Risk (a)	Contractor % of Risk (b)	Contractor Deductible (c)	Contractor Risk Contingency (d)	EMV of Owner's Risk Share (e)	Total Risk Cost (col. d + col. e) (f)	Risk Premium (col. f - ($60,000) (g)
0%	100%	$ 0	$80,170	$ 0	$80,170	$20,170
20	80	0	60,370	12,000	72,370	12,370
100	0	150,000	55,390	15,000	70,390	10,390
40	60	0	42,670	24,000	66,670	6,670
50	50	0	34,530	30,000	64,530	4,530
100	0	100,000	34,410	30,000	64,410	4,410
80	20	10,000	15,380	45,600	60,980	980
80	20	0	12,680	48,000	60,680	680
90	10	0	6,170	54,000	60,170	170
100	0	20,000	6,160	54,000	60,160	160
100	0	10,000	3,040	57,000	60,040	40
100	0	0	0	60,000	60,000	0

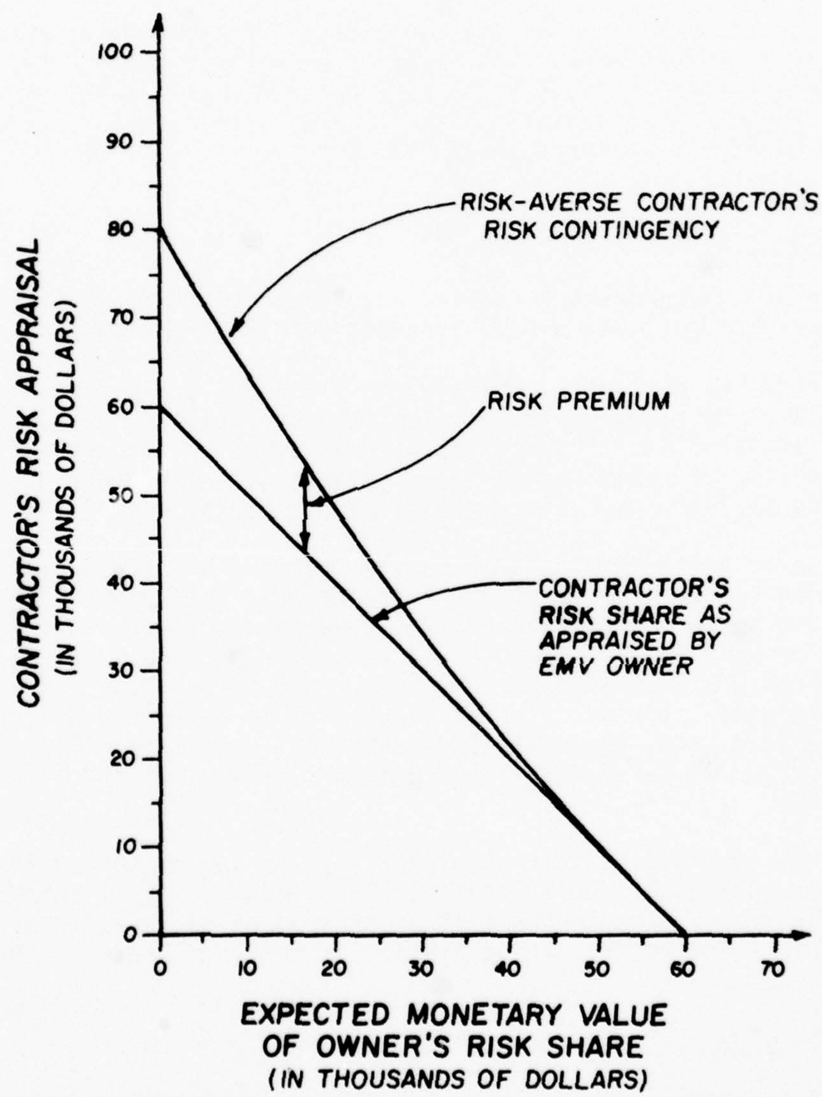

Figure 10. Contractor's risk appraisal as a function of EMV owner's risk share (from Table 1).

7 RISK-SHARING IMPLEMENTATION CONSIDERATIONS

This chapter identifies risk-sharing implementation considerations that should be examined by an owner when assessing risk allocation policy for procuring new construction.

Differing Utility Functions

Because of differing utility functions, the large owner may be better able to assume more of the risk. The owner may pay more in contingency costs than it is worth to have a contractor assume the risk because the contractor's contingency is based upon a utility function which may be more risk averse than the owner's.

Competition

There are three primary reasons why large owners may be able to obtain a more competitive bid by assuming more of the risk:

1. When the contractor must assume the risk, smaller contractors who are otherwise technically competent and competitive may not be in a financial position to bid competitively without exposing themselves to the possibility of catastrophic loss. However, if the owner assumes the risk, these smaller contractors may bid and increase competition.

2. Large contractors who prudently assess risks may be discouraged from bidding projects on which the contractor is assigned all of the risk. These large contractors realize they may be underbid by inexperienced or gambling contractors who do not properly assess the risk. Large contractors who match such bids can only make a reasonable profit if everything goes perfectly or if litigation is contemplated from the start. In this case, the owner could benefit from assuming more of the risk because these large, qualified contractors may bid and increase competition.

3. The possibility that an otherwise good contractor could be driven into bankruptcy and be unavailable to construct the owner's future jobs simply because the contractor happens to have a project when the 100-year flood occurs can be avoided if the owner assumes the risk.

Exculpatory Clauses

The easiest way for the owner to write a contract is to include a clause stating that the contractor is responsible for everything. Frequently, however, court proceedings find such exculpatory clauses unenforceable. In such cases, an owner is not assured of protection even

though a contingency is paid. However, by explicitly assuming more of the risk, the owner may obtain bids containing less contingency. Figure 11 illustrates the consequences of the use of exculpatory clauses.

EXCULPATORY CLAUSES	RISK EVENT: OCCURRENCE	RISK EVENT: NONOCCURRENCE
ENFORCEABLE	CONTRACTOR INCURS COSTS FOR WHICH CONTINGENCY AT LEAST PARTIALLY OFFSETS	JUSTIFIABLE CONTRACTOR COMPENSATION FOR RISK EXPOSURE
UNENFORCEABLE	OWNER INCURS ADDITIONAL COSTS: DELAYS, CLAIMS, LITIGATION	WINDFALL PROFIT FOR CONTRACTOR

Figure 11. Legal aspects of assigning risk to contractor.

Contractor's Financial Ability to Cover Assumed Risks

Even if exculpatory clauses are enforceable, the owner must assign the risk to a party who is financially able to bear it. As shown in Figure 12, if uncertain events for which the contractor included contingencies do not occur, the contractor realizes what appears to be a windfall profit. If the contractor could have covered the costs in the event of occurrence, then this apparent windfall profit in the non-occurrence case is justified compensation for the contractor's risk exposure. If, however, the contractor and surety would not have been able to cover the costs in the event of occurrence, the contingency paid by the owner is not justified.

FINANCIAL ABILITY TO PAY		RISK EVENT: OCCURRENCE	RISK EVENT: NONOCCURRENCE
	CAN PAY	CONTRACTOR INCURS COSTS FOR WHICH CONTINGENCY AT LEAST PARTIALLY OFFSETS	JUSTIFIABLE CONTRACTOR COMPENSATION FOR RISK EXPOSURE
	CAN'T PAY	CONTRACTOR AND/OR SURETY CANNOT FINANCIALLY COVER LOSSES. OWNER INCURS ADDITIONAL COSTS: DELAYS, CLAIMS, LITIGATION	WINDFALL PROFIT FOR CONTRACTOR

Figure 12. Financial aspects of assigning risk to contractor.

Contractor Default

Even if the contractor is bonded, a contractor default due to the occurrence of an event for which the contractor assumed the risk results in additional costs for the owner because of delays, claims, and possible litigation. It is likely that such a situation could be averted if the owner assumed more of the risk.

Type of Contract

A contract type other than firm-fixed price may be more appropriate when the distribution of possible project costs has a high variance. In this case, the cost of risk may be a relatively large portion of the total costs. If a different contract type is used, the owner may be able to avoid paying a contingency to the contractor which exceeds the amount the owner's utility function deems appropriate.

Better Risk Manager

A contractor's greatest assets are often experience and ingenuity. When the contractor assumes all of the risk, he has the most incentive to use his experience and ingenuity to properly manage risk. Therefore, the contractor may be in a better position than the owner to assume some risks. However, if the owner assumes some or all of the risk, the contractor should be provided proper incentives for efficient performance.

Control of Risk

Before assigning a risk, the owner should consider which party controls or influences the risk. Risks over which the contractor has no control or influence may best be assumed by the owner. Risks over which the contractor has some control may be appropriate for sharing. For example, the contractor normally selects the concrete formwork used in a construction project; therefore, the contractor should assume the risk for difficulties with it. Neither party controls the weather, but the contractor is often in a position to mitigate its effects by prudent job scheduling. Hence, the owner may not wish to completely assume this risk. The risk of an earthquake, which neither party controls, may be a risk the owner should either assume or require the contractor to be insured against.

It is of utmost importance to realize that many owners currently assign risk to others on the basis of noncontrol rather than on the basis of either control or financial ability to bear a risk. In other words, owners may be willing to assume a risk if they feel they completely control it. However, this applies to only a very small number of risks. The remainder of the risks are then dealt off to others on the assumption that since the owner does not control the risk, it should be given to someone else. The result is that the contractor is responsible for not only contractor-controlled risks, but also a large number of risks that neither the contractor nor the owner control. These "uncontrollable" risks are ones which the owner should consider for inclusion in a risk-sharing policy.

Incentives

When risk is shared, proper incentives must be maintained to assure efficient contractor performance. For example, a loosely interpreted rain delay clause could offer a profit incentive to a contractor, encouraging the contractor to send his employees home whenever the sky becomes overcast.

Administrative Costs

Implementing a risk-sharing policy involves a trade-off between reduced contingency costs and increased contract administration costs. When contracts are changed so that the owner assumes more risks, clauses specifying that risk be shared must be more detailed than broad exculpatory clauses passing all risks to the contractor. These more-detailed clauses, inspections, and additional record keeping increase both the preparation and the administration costs of the contracts.

Risk-sharing clauses must identify and define the risks as well as establish decision criteria which specify:

1. How to determine when an uncertain event occurs for which the owner assumes responsibility

2. Who determines the responsibility for the occurrence

3. How the owner's share of the damage is determined.

For example, a contract under which the owner assumes the cost of risk for "other than normal weather" requires a detailed clause defining "other than normal weather." The increased cost of administrative procedures may be more than offset by the owner's savings resulting from bids containing less contingency.

Owner's Personnel

If the objective of reducing the owner's expected total cost within a specified level of quality by receiving bids containing smaller contingencies has not been clarified to the owner's field representatives and fiscal officer, their actions may cause the contractor to perceive no change in his risk exposure. In this case, costly and lengthy litigation may result.

Contractor's Perception of Change

The success of a revised risk-sharing policy is largely dependent upon the contractor's perception of the change in the contractor's risk exposure. If the contractor's perception of the risk allocation does not change, the owner will not receive a more favorable bid. The contractor's perception of the change in risk allocation depends upon several factors influencing the contractor's interpretation of the risk-allocation clause:

1. The intent of the persons selecting the clause

2. The interpretation of the owner's field representatives

3. The interpretation of the owner's personnel responsible for approving additional funds.

Apparent Cost Overruns

On a risk-sharing project, the contractor's bid should contain less contingency. Because some of the uncertain events will probably occur, additional payments by the owner may be necessary. In the public sector, public and legislative apprehension may result when these "apparent" cost overruns and time extensions occur. In the private sector, the owners and officers are concerned. In both cases, prior explanation of the risk-sharing approach should be given to the public and/or company officers.

8 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. The application of utility theory to risk allocation in construction contracts can illustrate the cost effects of varying the owner's and contractor's share of the risk.

2. Increased risk assumption by large owners dealing with contractors who are not as large is justified by the savings that can be realized both initially through lower bid prices and throughout the project because of fewer delays, claims, and litigation resulting from the assignment of risks which contractors are not financially able to bear.

3. Potential implementation problems for a risk-sharing approach include the use of more detailed contract clauses, the need to assure that contractor incentives for efficient performance are maintained and the possibility that the public may incorrectly perceive apparent cost overruns. The success of risk sharing is also dependent upon the contractor's perception that his risk exposure has been changed. However, these problems appear minor in comparison to the potential benefits of lower contingencies and increased competition.

Recommendations

It is recommended that risk sharing be tested by implementing a few risk-sharing clauses in selected contracts, i.e., by including risk-sharing clauses as alternates to standard contracts. The use of these alternates should allow a direct comparison to the cost of currently used clauses. However, owners should be aware that the expected value of the owner's share of the risk should be deducted from the difference in bid prices to determine the expected savings. Changes in contract administration costs should also be considered. In addition, contractors should be expected to conservatively appraise a new clause, since they cannot be sure of how it will be interpreted during the progress of the contract. However, as the new clauses gain exposure, it is expected that contractors should approach them less conservatively.

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APPENDIX A: LIST OF RISKS IN CONSTRUCTION[7]

Following is a list of risks in the construction process. Owners should review this list when determining how current contracts address and assign these risks.

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[7] Committee on Responsibility, Liability, and Accountability for Risks in Construction, Exploratory Study on Responsibility, Liability, and Accountability for Risks in Construction (Building Research Advisory Board, National Academy of Sciences, 1978); Erikson, Carl A., Risk Sharing in Construction Contracts, Ph.D. Thesis (Department of Civil Engineering, University of Illinois at Urbana-Champaign, January 1979), pp 48-62.

O = OWNER
D = DESIGNER
C = CONTRACTOR

✓ = CONTROL OR INFLUENCE
* = NOT IN CONTROL BUT AFFECTED BY

RISK	TYPE OF RISK											
	CONSTRUCTION RISK								CONTRACTUAL RISK			
	PROJECT RELATED				OUTSIDE INFLUENCE							
	Controllable			Uncontrollable	Controllable			Uncontrollable	Controllable			Uncontrollable
	O	D	C		O	D	C		O	D	C	
MANAGEMENT												
Personal competence												
1. Owner									✓			
2. Design professionals									✓	✓		
3. Constructors									✓		✓	
4. Labor			✓	✓								
5. Government				✓				✓				
Senior management indecision									✓	✓	✓	
Mistakes in judgment	✓	✓	✓									
Quality of personnel/ supervision/management												
1. Overextended?	✓	✓	✓									
2 Not experienced?	✓	✓	✓									
OWNER												
Contract administration: degree to which owner and contractor agree on who does what									✓	✓	✓	
Time: span of contract	✓		*						✓		*	
Size: inherent problems of scale	✓	✓	*						✓	✓	*	
Size: package into a single contract many diverse sections which were previously awarded incrementally									✓	✓	*	
Separate contracts: coordination problems									✓			
Timely approvals									✓	✓	*	
Wide variability in the competence of contractors who meet minimum standards									✓		*	

O = OWNER
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RISK	TYPE OF RISK											
	CONSTRUCTION RISK								CONTRACTUAL RISK			
	PROJECT RELATED				OUTSIDE INFLUENCE							
	Controllable			Uncontrollable	Controllable			Uncontrollable	Controllable			Uncontrollable
	O	D	C		O	D	C		O	D	C	
DESIGN												
Design deficiencies: conflicts, omissions, interferences, incomplete or inadequate design	*	✓	*									
Personal competence: selection of competent and experienced designers so as to minimize errors, omissions, and changes in criteria and provide an economical design									✓	*	*	
Timely approvals									*	✓	*	
CONTRACTOR												
Geographic location relative to contractor's home office:												
1. Unfamiliar suppliers/labor/inspectors/politics			✓	✓							✓	
2. Management problems			✓									
Bid preparation												
1. Time									✓	✓	*	
2. Site visit and investigation	✓	✓	✓						✓	✓	*	
3. Planning and scheduling risk in forecasting, anticipation of changes	✓	✓	*	✓				✓				
4. Errors												
a. Judgment	*		✓									
b. Mistakes	*		✓									
c. Omissions	*		✓									
d. Interpretation		✓	✓									
5. Procedure to correct errors between owner, designer, contractor									✓	✓	✓	

RISK	TYPE OF RISK											
	CONSTRUCTION RISK								CONTRACTUAL RISK			
O = OWNER ✓ = CONTROL OR INFLUENCE	PROJECT RELATED				OUTSIDE INFLUENCE							
D = DESIGNER * = NOT IN CONTROL BUT AFFECTED BY	Controllable			Uncontrollable	Controllable			Uncontrollable	Controllable			Uncontrollable
C = CONTRACTOR	O	D	C		O	D	C		O	D	C	
Competitive environment											✓	
1. Number of bidders, familiar									*		✓	
2. Out of region?											✓	
3. Economy in general								✓			✓	
4. Contractor job volume:											✓	
a. Current jobs/this job/											✓	
anticipated other jobs									*		✓	
available												
b. Bonding capacity											✓	
c. Reputation											✓	
d. Overhead distribution to other jobs/breakeven point									✓		✓	
Contractor size												
1. Control											✓	
2. Expertise											✓	
3. Ability to settle modifications									*		✓	
a. Quality of legal department									*		✓	
b. Political influence,											✓	
c. Experience in specification interpretation											✓	
Diminution of management's right to manage,			✓	✓								
Site supervision and management			✓								✓	
Cost and ability of job site planning, execution, and control			✓									
Shopping by contractors,			✓									
Scheduling of work by contractors			✓									
Availability of financing			✓					✓				

O = OWNER
D = DESIGNER
C = CONTRACTOR
✓ = CONTROL OR INFLUENCE
* = NOT IN CONTROL BUT AFFECTED BY

RISK	TYPE OF RISK											
	CONSTRUCTION RISK								CONTRACTUAL RISK			
	PROJECT RELATED				OUTSIDE INFLUENCE							
	Controllable			Uncontrollable	Controllable			Uncontrollable	Controllable			Uncontrollable
	O	D	C		O	D	C		O	D	C	
INNOVATION/STANDARDIZATION/OBSOLESCENCE												
Innovative rather than traditional design		✓	*						✓	✓	*	
Special materials rather than standard materials/installed equipment	✓	✓	*						✓	✓	*	
Design of system or components which are unique or involve new technology.	✓	✓	*						✓	✓	*	
SPECIFICATIONS/CONTRACT TERMS												
Innovative systems or procedures	✓	✓	*						✓	✓	*	
Nonstandardized specifications									✓	✓	*	
Unduly onerous and unfair contract terms (biggest risk to surety)									✓	✓	*	
Refine contract provisions so as to clearly assign responsibilities and minimize risks									✓	✓	*	
Allocation of risks should be in line with comparable authority and financial benefits									✓	✓	*	
Statement in contract such as certain things "will be done as directed by the engineer"									✓	✓	*	
Ambiguous specifications: incomplete or confusing plans and specifications causing change orders										✓	*	

RISK	TYPE OF RISK											
	CONSTRUCTION RISK								CONTRACTUAL RISK			
	PROJECT RELATED				OUTSIDE INFLUENCE							
O = OWNER D = DESIGNER C = CONTRACTOR ✓ = CONTROL OR INFLUENCE * = NOT IN CONTROL BUT AFFECTED BY	Controllable			Uncontrollable	Controllable			Uncontrollable	Controllable			Uncontrollable
	O	D	C		O	D	C		O	D	C	
Incentive for contractor to disclose before bidding									*	✓	✓	
Failure of plans and specifications to display or reference all interagency agreements affecting the project									✓	✓	*	
CHANGES												
Design changes: owner changes in requirements for facility	✓	✓	*									
Designer changes due to mistake, conflict or whim	*	✓	*									
Adherence to "frozen" criteria feature: "freeze" design/engineering and regulatory as of construction start	*	✓	*	✓				✓				
Unilateral owner action on changes, design details, and work force									✓	✓	*	
Payment delays on change orders									✓	✓	*	
Impact: effect on unchanged work	✓	✓	*									
Price determination on changes									✓	✓	✓	
Changes/impact												
1. In specifications									✓	✓	*	
2. In method or manner of performance	✓	✓	*						✓	✓	*	
3. In owner furnished facilities, equipment, materials, services, or site	✓		*									
4. Directing acceleration of the performance of the work									✓	✓	*	

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	PROJECT RELATED				OUTSIDE INFLUENCE							
	Controllable			Uncontrollable	Controllable			Uncontrollable	Controllable			Uncontrollable
	O	D	C		O	D	C		O	D	C	
DISPUTES/CLAIMS/ADVERSARY RELATIONSHIPS												
Timely submission of claims and supporting data and documentation thereby giving an owner an earlier and better idea of the potential added costs being incurred in areas of dispute									*	✓	✓	
Runaway legal complications: mediation and arbitration vs litigation; excessive defense costs									✓	✓	✓	
Adversary relations: need more team building									✓	✓	✓	
DELAYS												
Effects of delays are serious because of inflation/escalation				✓				✓				
Delays due to:												
1. Third party delay/lawsuits				✓				✓				
2. Owner caused:												
a. Suspensions									✓		*	
b. Changes									✓		*	
c. Untimely approvals									✓		*	
d. Damage for delay									✓		*	
3. Governmental/regulatory								✓				
4. Acts of God								✓				
OUTSIDE CONTROLS												
Permits and licenses: owner permits, outside agencies' permits not obtained by awarding agency									✓		*	
Patent infringements	✓	✓	✓									

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	PROJECT RELATED				OUTSIDE INFLUENCE							
	Controllable			Uncontrollable	Controllable			Uncontrollable	Controllable			Uncontrollable
	O	D	C		O	D	C		O	D	C	
Congressional action												
1. Pending legislation												
a. Exports								√				
b. Clean air								√				
c. Tax laws								√				
2. Post bidding changes in: Government regulations, local laws and ordinances, codes					★	★	★	√				
3. Backfitting to comply with new regulations					★	★	★	√				
Public/community intervention: delays				√				√				
1. Intervenors				√								
2. Third party injunctions, initiation of legal action to halt construction once construction has begun				√								
Regulatory decision/indecision cost and compliance								√				
Environmental protection												
1. Disruption of natural ecosystems								√				
2. Quality of environment												
a. Water								√				
b. Air								√				
c. Noise								√				
3. Endangered species								√				
Social concerns/socioeconomic impact								√				
GENERAL ECONOMIC FACTORS												
Inflation/escalation								√				
Fluctuating interest costs								√				
Fluctuating taxes								√				

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	Controllable			Uncontrollable	Controllable			Uncontrollable	Controllable			Uncontrollable
	O	D	C		O	D	C		O	D	C	
Unforeseen economic factors:												
1. Embargoes								✓				
2. Controls								✓				
3. Shortages												
a. Energy				✓				✓				
b. Materials				✓				✓				
PHYSICAL ASPECTS												
Differing site conditions/ changed conditions:												
1. Owner's personnel must understand clause's objective									✓		*	
2. Owner and designer attitude on changed conditions									✓	✓	*	
3. Lack of owner's prompt recognition of changed conditions, lack of promptness in design decisions to meet the change									✓	✓	*	
Natural conditions, manmade hazards, acts of God												
1. Subsurface conditions												
a. Soil and rock characteristics	✓		✓	✓								
b. Earthquake	*		*	✓								
c. Groundwater		✓	✓	✓								
2. Geologic unknowns												
a. Adequate underground explorations: owner's limitation of investment in subsurface explorations	✓		*						✓			
b. Inaccurate delineation of existing subsurface structures		✓	*							✓		
c. Disclaimers as to subsurface data									✓	✓	*	

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	O	D	C		O	D	C		O	D	C	
Weather/seasonality/climate: other than normal												
1. Wind												
a. Hurricane					*		*	✓				
b. Tornado					*		*	✓				
2. Water												
a. Rainfall							✓	✓				
b. Floods							✓	✓				
c. Coastal surges							✓	✓				
d. Cofferdams							✓	✓				
3. Fire												
a. Manmade	✓		✓	✓	✓		✓	✓				
b. Natural	✓		✓	✓	✓		✓	✓				
4. Explosions	✓		✓	✓								
5. Toxic materials			✓	✓			✓	✓				
6. Transportation facilities				✓								
7. Utilities				✓								
8. Temporary facilities/ personnel facilities				✓								
SAFETY												
Contractor is responsible for the safety and integrity of the structure during construction			✓								✓	
Inconveniences and hazards to the public and to contiguous structures attributable to the construction	*	*	✓	✓								
Physical welfare of the worker	*	*	✓	✓								
Safety of public using the finished project and during construction	✓	*	✓	✓								
Surrounding properties	✓	*	✓	✓								

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	O	D	C		O	D	C		O	D	C	
OSHA: interference with project management resulting from frequently unwarranted inspections			✓	✓								
INSURANCE/BONDING/LIABILITY/DAMAGE												
Bonding												
1. Bid bond: failure to enter into contract	✓		✓						✓		✓	
2. Payment bond: nonpayment of creditors arising out of contract	✓		✓						✓		✓	
3. Performance bond: failure of specific performance, failure to complete contract according to the plans and specifications	✓		✓						✓		✓	
Untimely completion/delays	✓		✓						✓		✓	
Insurance												
1. Personal injury/loss of life												
2. Health impairment												
a. Employees' workman's compensation	✓	✓	✓									
b. Others	✓	✓	✓									
3. Property damage												
a. To others	✓	✓	✓									
b. To firm's assets	✓	✓	✓									
c. To project:												
(1) Acts of God	*		✓									
(2) Failure	*		✓									
(a) Design		✓										
(b) Construction			✓									
(3) Acts of others	✓		✓									
4. Security/theft/vandalism			✓	✓								
Tortious acts			✓									
Insurance considerations												
1. Wrap up or contractor's	✓		✓									
2. Cheap to sue, expensive to defend	✓	✓	✓									

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	O	D	C		O	D	C		O	D	C	
SUBCONTRACTORS												
Timely availability at an acceptable price			√	√								
Nonperformance			√									
Unacceptable performance			√									
Timely performance			√									
Coordination problems			√									
Omissions from work; i.e., neither mechanical or electrical included item			√									
Minority participation			√	√								
LABOR												
Productivity/performance: site and shop			√	√								
Availability/shortages			√	√				√				
Skill level			√	√								
Union vs nonunion			√									
Crew coordination			√									
Strikes												
1. Strike at supplier's plant			√	√				√				
2. Incentive for contractor to settle low if cost plus	√		√									

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	O	D	C		O	D	C		O	D	C	
Socioeconomic:												
1. Equal employment opportunity			✓	✓			✓	✓				
2. Handicapped			✓	✓			✓	✓				
3. Minorities			✓	✓			✓	✓				
4. Convict labor			✓	✓			✓	✓				
5. Affirmative action, etc.			✓	✓			✓	✓				
Morale:												
1. Doing job twice	✓	✓	✓	✓				✓				
2. Backfitting	✓	✓	✓	✓				✓				
Unsafe acts of labor			✓	✓								
Instability			✓	✓								
Jurisdictional problems			✓	✓				✓				
Union work rules: featherbedding			✓	✓				✓				
Slowdowns/stoppages			✓	✓				✓				
Arbitration												
Restrictive hiring halls			✓	✓				✓				
Escalation provisions			✓									
Area-wide bargaining agreements/ same expiration date			✓	✓								
MATERIALS AND INSTALLED EQUIPMENT/ SUPPLIERS												
Timely availability at an acceptable price			✓	✓				✓				
Timely delivery, especially major equipment			✓	✓				✓				

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	Controllable			Uncontrollable	Controllable			Uncontrollable	Controllable			Uncontrollable
	O	D	C		O	D	C		O	D	C	
What if not available:												
Controlled material			*				*	✓				
Obsolete specifications			*				*	✓	✓			
Shortages			*	✓			*	✓				
Deficiencies in material or equipment			*	✓				✓				
Unpredictable costs			*	✓			*	✓				
Innovative material and equipment		✓	*							✓	*	
Owner furnished	✓		*						✓		*	
Fabrication problems			*	✓				✓				
"Or equal" clause interpretation									✓	✓	*	
EQUIPMENT (CONSTRUCTION)												
Breakdowns: (who pays?) incentives to use new/old equipment	✓		✓									
Timely availability at an acceptable cost			✓	✓				✓				
Technological changes/obsolescence			✓									
Productivity/performance			✓	✓				✓				
How are costs determined?									✓		✓	
Standardized equipment		✓	*							✓	*	

APPENDIX B: REVIEW OF EXISTING CATEGORIZATIONS

Seven existing categorizations which reflect the widely differing views of seven published authorities on risk were reviewed to develop a categorization scheme for risks in the construction process.

G. E. Mason[8]

Mason has classified risks into the areas of:

1. Nonperformance
2. Situation changes
3. Cost of dispute settlements
4. Liability losses
5. Damage to the project during construction.

Mason formulated four methods for managing these risks:

1. Risk avoidance
2. Risk abatement
3. Risk retention
4. Risk transfer.

Mason's work concentrates on the traditional bonding and insurance areas, which correspond to the nonperformance and liability-loss classifications, respectively. The viewpoint is primarily that of the owner, and the information presented is intended to aid in the selection of contract provisions.

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[8] G. E. Mason, A Quantitative Risk Management Approach to the Selection of Construction Contract Provisions, Technical Report No. 173 (The Construction Institute, Department of Civil Engineering, Stanford University, April 1973), pp 26 to 61.

S. L. Shafer[9]

Shafer discusses the use of a risk analysis approach for cost estimating. He categorizes risk elements as follows:

1. Design elements
   a. Engineering changes
   b. Field changes
2. Contingency elements
   a. Labor
   b. Other job conditions
   c. Pricing.

T. M. Frisby[10]

Frisby classifies risks as follows:

1. Entrepreneurial risks
2. Project risks
3. Resources to be managed
4. External factors.

Frisby's work is apparently intended to be used at the management level of a construction firm.

G. T. Kraemer[11]

Kraemer considers risk assessment from a viewpoint more typical of the aerospace, electronic, or tooling industries rather than of the

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9 S. L. Shafer, "Risk Analysis for Capital Projects Using Risk Elements," Transactions of the American Association of Cost Engineers (1974), pp 218-223.

10 T. M. Frisby, Risk Management, presented at the U.S. Army Engineer District Mobile Area and Resident Engineers Conference (21-23 July 1976), pp I-1 to I-17.

11 G. T. Kraemer, "Meaningful Risk Assessment," Transactions of the American Association of Cost Engineers (1976), pp 127-132.

construction industry. Kraemer considers an appropriate categorization scheme to be:

1. Cost risk
2. Schedule risk
3. Technical risk.

M. Gates[12]

Gates places construction contracting contingencies into four categories:

1. Mistakes
2. Subjective uncertainties
3. Objective uncertainties
4. Chance variations.

Gates considers risks which necessitate the use of contingencies from the viewpoint of a contractor estimating costs for a project.

C. W. Marshall[13]

Marshall considers three major factors to be important in formulating a measure of contractor risk arising from cost variations:

1. Cost variability due to real world uncertainty
2. Contract structure (including contract type)
3. Contractor's utility for money.

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12 M. Gates, "Bidding Contingencies and Probabilities," Journal of the Construction Division, ASCE, Vol 97, No. CO2, Proc. Paper 8524 (November 1971), pp 277-303.

13 C. W. Marshall, "Quantification of a Contractor Risk," Naval Research Logistics Quarterly, Vol 16, No. 4 (December 1969), pp 531-541.

Benson and Colwell[14]

Benson and Colwell consider risks from the point of an owner in the process of selecting the type of contract to be used for a construction project.

1. Factors related to the day-to-day operation of the construction effort

2. Resources necessary to construct the project which are beyond the control or influence of the contractor

3. Factors that are a function of or related to the work or the work site.

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14 L. B. Benson and G. E. Colwell, Construction Contract Type Selection Procedures, Technical Report P-98/ADA066384 (CERL, February 1979).

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